Joint Venture for Product Innovation and Cartel Stability under Vertical Di¤erentiation

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Abstract

We describe a vertically di¤erentiated market where …rms choose between activating either independent ventures leading to distinct product qualities, or a joint venture for a single quality. Then, …rms either repeat the one-shot Nash equilibrium forever, or behave collusively, according to discount factors. We prove that there exists a parameter region where the joint venture makes it more di¢cult for …rms to sustain collusive behaviour, as compared to independent ventures. Therefore, public policies towards R&D behaviour should be designed so as not to become inconsistent with the pro-competitive attitude characterising the current legislation on marketing practices.

J.E.L. classi…cation: C72, D43, L13

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1 Introduction

Oligopoly theory has produced a relevant literature on repeated market interaction. The relative efficiency of Bertrand and Cournot competition in stabilizing cartels composed by firms whose products are imperfect substitutes has been analysed by Deneckere (1983), Rothschild (1992) and Albæk and Lambertini (1998), showing that when substitutability between products is high, collusion is better supported in price-setting games than in quantity-setting games, while the reverse is true in case of low substitutability.[1] Majerus (1988) has proved that this result is not confirmed as the number of firms increases. These contributions compare Cournot and Bertrand supergames to conclude that a quantity-setting cartel should almost always be preferred to a price-setting cartel on stability grounds.[2] Finally, the influence of endogenous product differentiation on the stability of collusion in prices has been investigated by Chang (1991, 1992), Ross (1992) and Häckner (1994, 1995, 1996). The main finding reached by these contributions is that, under vertical differentiation, collusion is more easily sustained, the more similar the products are, while the opposite applies under horizontal differentiation.

The consequences of collusion on the extent of optimal differentiation in the horizontal differentiation model have also received attention. Friedman and Thisse (1993) have considered a repeated price game in the horizontal framework and found out that minimum differentiation obtains if firms collude in the market stage. In most of these models, although differentiation can be endogenously determined by firms through strategic interaction, the issue of cartel stability is studied by making the degree of differentiation vary symmetrically around the ideal midpoint of the interval of technologically feasible or socially preferred varieties, leading to the conclusion that producers may prefer to choose the characteristics of their respective goods differently from what profit maximization would suggest, if this helps them minimize the incentive to deviate from the implicit cartel agreement.

[1] The same question is addressed in Lambertini (1996), where the evaluation of cartel stability under Bertrand and Cournot behaviour is carried out in terms of the concavity/convexity of the market demand function.

[2] This approach cannot grasp any strategic interaction behind the choice of the market variable. Using the same demand structure as in Deneckere (1983) and analysing asymmetric cartels where one firm is a Bertrand agent while the other is a Cournot one, Lambertini (1997) proves that the choice of the market variable in order to stabilize implicit collusion produces a Prisoner's Dilemma.

To our knowledge, little attention has been paid so far to the interplay between …rms' technological decisions and their ability to build up and maintain collusive agreements over time. This is a relevant issue, in that public authorities prosecute collusive market behaviour, while they seldom discourage cooperation in R&D activities. Indeed, there exist many examples of policy measures designed so as to stimulate the formation of research joint ventures.[3] However, encouraging cooperative R&D and discouraging market collusion can be mutually inconsistent moves, if R&D cooperation tends to facilitate collusion in the product market.

In this respect, Martin (1995) analyses the strategic e¤ects of a research joint venture (JV henceforth) designed to achieve a process innovation for an existing product. Then, the product is marketed by …rms engaging in repeated Cournot behaviour over an in…nite time horizon. Martin shows that cooperation in process innovation enhances implicit collusion, which can jeopardise the welfare advantage of eliminating e¤ort duplication through the JV. This result has potential implications for the case of product innovation as well.[4]

We reassess Martin's framework, by considering a vertically di¤erentiated market where …rms are given the possibility of choosing between activating either independent ventures leading to distinct product qualities, or a joint venture for a single quality, aimed at reducing the initial R&D expenditure vis à vis independent ventures. Then, …rms market the product(s) over an in…nite horizon. In doing so, they either repeat the one-shot Nash equilibrium forever, or behave collusively, according to their intertemporal discounting. In such a setting, we prove that there exists a parameter region where Martin's conclusion is reversed, i.e., the JV makes it more di¢cult for …rms to sustain collusive behaviour in the market supergame, as compared to independent ventures. This holds independently of whether …rms set prices or quantities during the supergame. Our result entails that public policies towards the R&D behaviour of …rms should be tailored case by case, so as not to become inconsistent with the pro-competitive attitude characterising the

[3] See the National Cooperative Research Act in the US; EC Commission (1990); and, for Japan, Goto and Wakasugi (1988).

[4] Lambertini, Poddar and Sasaki (1998) adopt the same view as in Martin (1995), although they consider the relationship between standardization and the stability of implicit cartel agreeements. See also Lambertini, Poddar and Sasaki (2000). Cabral (1996), in a somewhat dissimilar vein, proves the possibility that competitive pricing is needed to sustain more e¢cient R&D agreements.

current legislation on marketing practices.

The remainder of the paper is structured as follows. The basic model of vertical di¤erentiation is described in section 2. Section 3 describes the case of collusion along the frontier of monopoly pro…ts. Section 4 deals with partial collusion under either Cournot or Bertrand behaviour. Finally, section 6 provides concluding remarks.

2 The vertical di¤erentiation model

We adopt a well known model of duopoly under vertical di¤erentiation (see Gabszewicz and Thisse, 1979, 1980; Motta, 1993; Aoki and Prusa, 1997; Lehmann-Grube, 1997; Lambertini, 1999, inter alia).[5] Two single-product …rms, labelled as H and L, produce goods of (di¤erent) qualities q_H and $q_L \in [0, \infty)$, with $q_H \geq q_L$, through the same technology, $C(q_i) = cq_i^2$, with $c > 0$. This can be interpreted as …xed cost due to the R&D e¤ort needed to produce a certain quality, while variable production costs are assumed away. Products are o¤ered on a market where consumers have unit demands, and buy if and only if the net surplus from consumption $v_\theta(q_i, p_i) = \theta q_i - p_i \geq 0$, where p_i is the unit price of the good of quality q_i, purchased by a generic consumer whose marginal willingness to pay is $\theta \in [0, \overline{\theta}]$. We assume that θ is uniformly distributed with density one over such interval, so that the total mass of consumer is $\overline{\theta}$.

Firms interact over $t \in [0, \infty)$, as follows:

- At $t = 0$, they conduct R&D towards the development of product quality, through either a joint venture (JV henceforth) or independent ventures (IV henceforth). If …rms undertake a joint venture, then $q_i = q_j = q$ and each …rm bears half the development cost, $cq^2/2$. Otherwise, …rms market di¤erentiated products, each of them bearing the full development cost of their respective varieties, cq_i^2.[6]

- Over $t \in [1, \infty)$, …rms market the product(s) resulted from previous R&D activity, either à la Cournot or à la Bertrand.

[5] A di¤erent model is used in Shaked and Sutton (1982, 1983), where …xed costs are exogenous.

[6] The R&D e¤orts of …rms operating in vertically di¤erentited markets are investigated in Beath et al. (1987), Motta (1992), Dutta et al. (1995), Rosenkranz (1995, 1997), van Dijk (1996). In particular, Motta (1992) and Rosenkranz (1997) describe the incentives towards cooperative R&D.

- In the infinitely long marketing phase, firms may collude if their respective time discounting allows them to do so. Otherwise, they always play à la Nash. Define as δ_i the discount factor of firm i; and $\delta_i^I(K)$ the critical threshold for the stability of collusion, with superscript $I = B; C$ standing for Bertrand and Cournot, and $K = IV; JV$; indicating the organizational design chosen for the R&D phase.

As a first step, observe that the locations of indifferent consumers along $[0; \overline{\theta}]$ are:

$$\theta_H = \frac{p_H - p_L}{q_H - q_L}\ ;\ \theta_L = \frac{p_L}{q_L} \tag{1}$$

where θ_H is the marginal willingness to pay of the consumer who is indifferent between q_H and q_L; and θ_L is the marginal willingness to pay of the consumer who is indifferent between q_L and not buying at all. Then, market demands are

$$x_H = \overline{\theta} - \theta_H\ ;\ x_L = \theta_H - \theta_L\ . \tag{2}$$

Notice that (2) can be inverted to yield the relevant demand functions for the Cournot case:

$$p_H = q_H\left(\overline{\theta} - x_H\right) - q_L x_L\ ;\ p_L = q_L\left(\overline{\theta} - x_H - x_L\right)\ . \tag{3}$$

At any $t \geq 1$; firm i obtains revenues $R_i^I = p_i x_i$; $I = B; C$. The discounted flow of profits over the whole game is then:

$$\pi_i^I = \begin{cases} \dfrac{\delta_i}{1-\delta_i} \cdot R_i^I(q_i; q_j) - c q_i^2 \text{ under } IV \\[2ex] \dfrac{\delta_i}{1-\delta_i} \cdot R_i^I(q) - \dfrac{cq^2}{2} \text{ under } JV \end{cases} \tag{4}$$

To model collusion in marketing, we adopt the Perfect Folk Theorem (PFT henceforth; see Friedman, 1971), where the infinite reversion to the one-shot Nash equilibrium is used as a punishment following any deviation from the prescribed collusive path.[7] The collusive path can instruct firms to collude either fully (i.e., at the Pareto frontier of monopoly profits) or partially, at

[7] There exist other (less grim) penal codes (see Abreu, 1986; 1988; Abreu, Pearce and Stacchetti, 1986; Fudenberg and Maskin, 1986), using symmetric optimal punishments. However, the asymmetry of our model prevents us from adopting optimal punishments. For the application of optimal punishments in a symmetric duopoly model with product differentiation, see Lambertini and Sasaki (1999, 2000).

any pair of prices or quantities such that per-period individual revenues are at least as large as the Nash equilibrium revenues.

Define:

[1] The instantaneous best reply of firm i as α_i^*:

[2] The collusive action as $\alpha^{coll} \in \left(\min \left\{ \alpha^N; \alpha^M \right\}; \max \left\{ \alpha^N; \alpha^M \right\} \right); \alpha = p; x$:

[3] The collusive revenues to firm i as $R_i^{coll}(\cdot)$; $(\cdot) = \{q; (q_i; q_j)\}$:

[4] The one-shot Nash revenues to firm i as $R_i^N(\cdot)$:

[5] The one-shot deviation revenues to firm i as $R_i^D(\cdot)$:

The rules of the PFT establish what follows:

- At $t = 0$; firms play α^{coll}:
- At $t \geq 1$; firms play α^{coll} iff $\alpha_i = \alpha^{coll}$ at $t - 1$ for all i ; firms play α_i^* otherwise.

Definitions [3-5] and the rules of PFT yields that implicit collusion at α^{coll} is sustainable iff

$$\delta_i \geq \delta_i(K) = \frac{R_i^D(\cdot) - R_i^{coll}(\cdot)}{R_i^D(\cdot) - R_i^N(\cdot)} \quad \text{for all } i : \tag{5}$$

In the next section, we quickly deal with the case of full collusion, where $\alpha^{coll} = \alpha^M$:

3 Full collusion

First, notice that when firms operate along the frontier of monopoly profits, they are indifferent between settting prices or output levels. Therefore, we confine our attention to the Bertrand case.

Suppose firms choose independent ventures at $t = 0$: Then, over $t \in [1; \infty)$, they should market different products. We are going to show that this cannot be an equilibrium. At any $t \in [1; \infty)$, the cartel aims at

$$\max_{p_H; p_L} R^M = R_H^B(q_H; q_L) + R_L^B(q_L; q_H) : \tag{6}$$

Monopoly prices are:

$$p_H^M = \frac{\overline{\theta} q_H}{2} \, ; \; p_L^M = \frac{\overline{\theta} q_L}{2} \, ; \tag{7}$$

at which $x_H^M = \frac{\overline{\theta}}{2}$, while $x_L^M = 0$. Therefore,

$$\pi_H^B = \frac{\delta_H}{1 - \delta_H} \cdot \frac{\overline{\theta}^2 q_H}{4} - c q_H^2 \, ; \; \pi_L^B = -c q_L^2 \, . \tag{8}$$

On the basis of the above result, independent ventures imply that, for all $q_L \in (0, q_H)$, the low-quality firm would exit, getting thus zero profits. Alternatively, firm L may produce $q_L = q_H$. This immediately entails that $\delta_i^B = 1/2$ for all i, as firms offer homogeneous goods.

It needs no proof to show that the same holds in the case of a joint venture, as this would yield product homogeneity as a result of technological decisions taken at $t = 0$. We have thus proved the following:

Lemma 1 Under full collusion, the low-quality product enjoys zero demand. As a consequence, firms will only supply homogeneous goods, with $JV \succ IV$ due to the cost-saving effect.

Corollary 1 Under full collusion in prices, $\delta_i^B = 1/2$ for all i, independently of firms' venture decisions.

As to the Cournot case, notice that, as long as firms provide different qualities, we have

$$x_H^M = \frac{\overline{\theta}}{2} \, ; \; x_L^M = 0 \tag{9}$$

which again entails that the low-quality firm survives only if $q_L = q_H$, either because firms activate a JV, or because firms develop the same quality independently of each other. As a result, we can state the following:

Lemma 2 Under full collusion in quantities, $\delta_i^C = 9/17$ for all i, independently of firms' venture decisions.

In summary, independently of the market variable chosen for the supergame over $t \in [1, \infty)$, the firms' venture decisions at $t = 0$ have no bearings on the stability of collusion, as setting either monopoly prices or quantities induces firms to play a supergame with homogeneous goods.

4 Partial collusion

Here, we investigate the bearings of technological choices on cartel stability, under the assumption that firms may activate partial collusion, i.e., they may collude at any $\alpha^{coll} \in \left[\min\left\{\alpha^N, \alpha^M\right\}, \max\left\{\alpha^N, \alpha^M\right\}\right], \alpha = p, x.$

4.1 Cournot behaviour

Consider partial collusion at $x^{coll} \in \left(x^M, x^N\right)$, for a generic quality pair $\{q_H, q_L\}$. In the limit, as $q_L \to q_H$, we obtain the description of the JV case.

We define the partially collusive output of firm i as:

$$x_i^{coll} = a x_i^N + (1 - a) x_i^M \; ; \; a \in (0, 1) \; ; \tag{10}$$

where $x_i^M = x^M/2 = \bar{\theta}/4$ and[8]

$$x_H^{CN} = \frac{\bar{\theta}\,(2q_H - q_L)}{4q_H - q_L} \; ; \; x_L^{CN} = \frac{\bar{\theta} q_H}{4q_H - q_L} \, . \tag{11}$$

The associated Nash equilibrium revenues are:

$$R_H^{CN} = \frac{\bar{\theta}^2 q_H \,(2q_H - q_L)^2}{(4q_H - q_L)^2} \; ; \; R_L^{CN} = \frac{\bar{\theta}^2 q_H^2 q_L}{(4q_H - q_L)^2} \, . \tag{12}$$

Substituting (11) into (10) and rearranging, we have:

$$x_H^{coll} = \frac{\bar{\theta}\,[4q_H (1 + a) - q_L (1 + 3a)]}{4\,(4q_H - q_L)} \; ; \; x_L^{coll} = \frac{\bar{\theta}\,[4q_H - q_L (1 - a)]}{4\,(4q_H - q_L)} \tag{13}$$

which allow to calculate R_i^{Ccoll}:

$$R_H^{Ccoll} = \frac{\bar{\theta}^2\,[4q_H^2 (3 - a) - q_H q_L (7 - 3a) + q_L^2 (1 - a)]\,[4q_H (1 - a) - q_L (1 + 3a)]}{16\,(4q_H - q_L)^2}$$
$$R_L^{Ccoll} = \frac{\bar{\theta}^2 q_L\,[2q_H\,(2 - a) - q_L (1 + a)]\,[4q_H - q_L (1 - a)]}{8\,(4q_H - q_L)^2} \tag{14}$$

[8] We omit the explicit derivation of the Nash equilibrium quantities, as it is well known from previous literature (see Motta, 1993).

The deviation from x_i^{coll} remains to be described. The best reply of firm j to x_i^{coll} is given by:[9]

$$x_H^{DC} = \frac{\bar{\theta}\left[(4q_H - q_L)^2 - aq_L^2\right]}{8q_H\,(4q_H - q_L)}\,;\; x_H^{DC} = \frac{4\bar{\theta}q_H(3-a) - 3\bar{\theta}q_L(1-a)}{8\,(4q_H - q_L)} \tag{15}$$

yielding deviation revenues:

$$R_H^{DC} = \frac{\bar{\theta}^2\left[(4q_H - q_L)^2 - aq_L^2\right]^2}{64q_H\,(4q_H - q_L)^2}\,;\; R_L^{DC} = \frac{\bar{\theta}^2 q_L\left[4q_H(3-a) - 3\bar{\theta}q_L(1-a)\right]^2}{64\,(4q_H - q_L)^2}\,. \tag{16}$$

We are now able to write the expressions for the critical threshold of the discount factors:

$$\delta_H^C = \frac{(1-a)\,(2q_H - q_L)^2\,(4q_H - q_L)^2}{q_L^2\left[32q_H^2 - 16q_Hq_L + q_L^2(1-a)\right]}\,; \tag{17}$$

$$\delta_L^C = \frac{(1-a)\,(4q_H - q_L)^2}{(4q_H - 3q_L)\left[4q_H(5-a) - 3q_L(1-a)\right]}\,. \tag{18}$$

Notice that the above critical thresholds are independent of $\bar{\theta}$; and can be plotted over the space $\{a; q_L\}$; after setting $q_H = 1$.[10] This is done in figures 1 and 2.

[9] Both x_H^D and x_L^D are admissible for all $a \in (0;1]$ and $q_L \in (0;q_H]$: As usual, deviation against a collusive output never drives the cheated firm out of business, and never makes the deviator a monopolist.

[10] Note that this normalisation involves no loss of generality, since the same plots would obtain by rewriting δ_i^C in terms of the quality ratio $q_L/q_H \in (0;1]$:

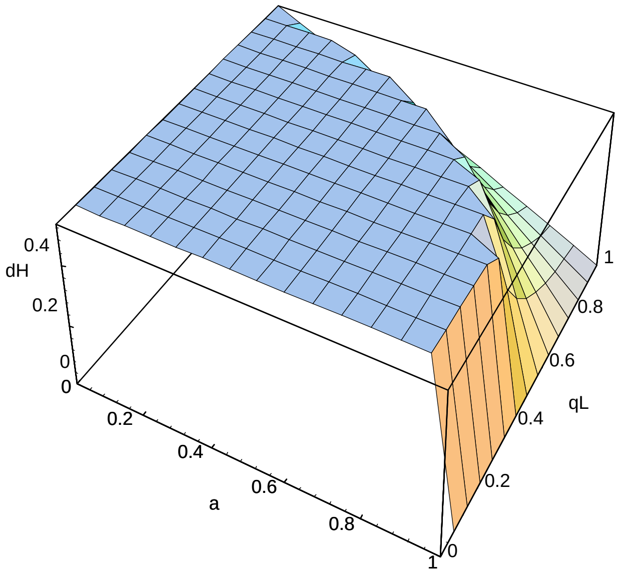

Figure 1. Plot of $\pm^C_H$ over $fa; q_L g$, with a 2 $[0; 1]$ and q_L 2 $[0; 1]$.

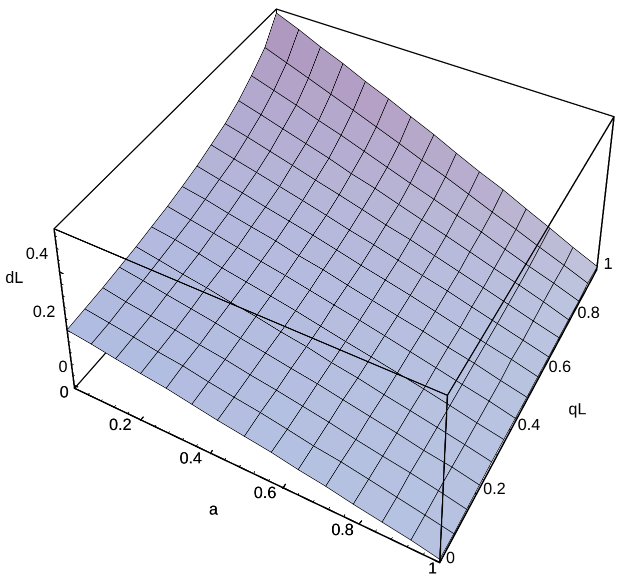

Figure 2. Plot of $\pm^C_L$ over $fa; q_L g$, with a 2 $[0; 1]$ and q_L 2 $[0; 1]$.

Observe …gure 1. The range of $\pm^C_H$ is truncated at 9/17 to put into evidence the parameter region wherein independent ventures make it easier for the high-quality firm to sustain quantity collusion, as compared to a joint venture. The equation of the border at which $\delta_H^C = 9/17$ is:

$$\hat{a} = \frac{2q_L^4 - 15q_L^3 + 149q_L^2 - 408q_L + 272}{2q_L^4 - 51q_L^3 + 221q_L^2 - 408q_L + 272}. \tag{19}$$

All combinations of $\{a; q_L\}$ defining a point along the downward sloping surface in figure 1, define levels of partial collusion and low quality such that independent ventures favour collusion as compared to a joint venture. The opposite holds for any point such that

$$a \in \left(0; \frac{2q_L^4 - 15q_L^3 + 149q_L^2 - 408q_L + 272}{2q_L^4 - 51q_L^3 + 221q_L^2 - 408q_L + 272}\right). \tag{20}$$

Consider now figure 2. For any combination of a and q_L in the admissible range, $\delta_L^C \leq 9/17$; holding as an equality at $\{a = 0; q_L = q_H\}$.[11]

The foregoing analysis allows us to state the following:

Proposition 1 For all $a \in (\hat{a}; 1]$; implicit collusion is more easily sustained under independent ventures than under a joint venture. For all $a \in [0; \hat{a})$; the opposite holds.

This means that, given a generic quality ratio q_L/q_H; independent ventures are preferable to a joint venture in terms of cartel stability, if firms collude not too far above the disagreement point given by the one-shot Cournot equilibrium. The shape of $\hat{a}$ shows that, as far as cartel stability is concerned, IV tends to become more and more advantageous compared to JV as product differentiation decreases. In the limit, as $q_L/q_H \to 1$; IV ensures $\delta_i^B < 1/2$ for all $a \in (0; 1]$.

Alternatively, the above result can be reformulated as follows. As a increases (that is, as the level of collusion weakens towards the Cournot-Nash output), the range of q_L/q_H wherein IV ensures $\delta_i^B < 1/2$ increases. The intuition is that, if collusion is only slightly above the Nash equilibrium profits, than deviation is scarcely profitable and this drastically contributes to stabilise implicit collusion.

[11] Notice that, in both plots, δ_i^C becomes negative if a is sufficiently large and q_L/q_H is sufficiently low, due to the fact that deviation profits become lower than collusive profits. In such a case, it can be assumed $\delta_i^C = 0$; so that any $\delta_i \geq 0$ ensures that the low-quality firm does not cheat. Clearly, this has no particular bearings on our analysis.

4.2 Bertrand behaviour

Turn now to the case where firms are price-setters and try to collude at $p^{coll} \in [p^N; p^M]$, for a generic quality pair $\{q_H; q_L\}$. Again, in the limit, as $q_L \to q_H$, we obtain the picture of the JV case.

Define the partially collusive price of firm i as:

$$p_i^{coll} = ap_i^N + (1 - a)p_i^M \; ; \; a \in (0; 1) \; ; \tag{21}$$

where $p_i^M = \overline{\theta} q_i / 2$ and[12]

$$p_H^N = \frac{2\overline{\theta} q_H (q_H - q_L)}{4q_H - q_L} \; ; \; p_L^N = \frac{\overline{\theta} q_L (q_H - q_L)}{4q_H - q_L} : \tag{22}$$

The associated Nash equilibrium revenues are:

$$R_H^{BN} = \frac{\overline{\theta}^2 q_H (2q_H - q_L)^2}{(4q_H - q_L)^2} \; ; \; R_L^{BN} = \frac{\overline{\theta}^2 q_H^2 q_L}{(4q_H - q_L)^2} : \tag{23}$$

Substituting (22) into (21) and rearranging, we have:

$$p_H^{coll} = \frac{\overline{\theta} q_H [4q_H - q_L(1 + 3a)]}{2(4q_H - q_L)} \; ; \; p_L^{coll} = \frac{\overline{\theta} q_L [2q_H (2 - a) - q_L(1 + a)]}{2(4q_H - q_L)} \tag{24}$$

which allow to calculate R_i^{Bcoll}:

$$\begin{aligned} R_H^{Bcoll} &= \frac{\overline{\theta}^2 q_H [4q_H - q_L(1 - a)][4q_H - q_L(1 + 3a)]}{4(4q_H - q_L)^2} \\ R_L^{Bcoll} &= \frac{\overline{\theta}^2 a q_H q_L [2q_H (2 - a) - q_L(1 + a)]}{2(4q_H - q_L)^2} \end{aligned} \tag{25}$$

Now consider the deviation from p_i^{coll}. The best reply of firm i against the collusive price p_j^{coll} is:

$$\begin{aligned} p_H^{BD} &= \frac{\overline{\theta} [8q_H^2 - 2q_H q_L (3 + a) + q_L^2 (1 - a)]}{4(4q_H - q_L)} \\ p_L^{BD} &= \frac{\overline{\theta} q_L [4q_H - q_L(1 + 3a)]}{4(4q_H - q_L)} \end{aligned} \tag{26}$$

[12] Again, the explicit derivation of the Nash equilibrium prices is omitted for the sake of brevity (see Choi and Shin, 1992; Motta, 1993).

The corresponding output levels for the cheating firm are:

$$x_H^{BD} = \frac{\bar{\theta}\left[8q_H^2 - 2q_H q_L(3+a) + q_L^2(1-a)\right]}{4\left(4q_H^2 - 5q_H q_L + q_L^2\right)}$$
$$x_L^{BD} = \frac{\bar{\theta} q_H\left[4q_H - q_L(1+3a)\right]}{4\left(4q_H^2 - 5q_H q_L + q_L^2\right)} \tag{27}$$

Notice that deviation outputs (27) are admissible for all values of $\{a; q_H; q_L\}$ such that $x_i^{BD} \leq \bar{\theta}$; which entails the following restrictions, for all positive $\bar{\theta}$:

$$x_H^{BD} \leq \bar{\theta} \text{ for all } \frac{q_L}{q_H} \in \left[0; \frac{7-a-\sqrt{a^2-22a+25}}{3+a}\right]; \tag{28}$$

$$x_L^{BD} \leq \bar{\theta} \text{ for all } \frac{q_L}{q_H} \in \left[0; \frac{19-3a-\sqrt{9a^2-114a+169}}{8}\right]: \tag{29}$$

The admissible range for the quality ratio in (29) is larger than in (28), i.e.,

$$\frac{19-3a-\sqrt{9a^2-114a+169}}{8} \geq \frac{7-a-\sqrt{a^2-22a+25}}{3+a} \;\; \forall a \in [0;1]: \tag{30}$$

The above inequality entails that, as intuition would suggest, it is easier for the high-quality than for the low-quality firm to become a monopolist.

If (29) and (29) are met, then deviation revenues are:

$$R_H^{BD} = \frac{\bar{\theta}^2\left[8q_H^2 - 2q_H q_L(3+a) + q_L^2(1-a)\right]^2}{16\left(q_H - q_L\right)\left(4q_H - q_L\right)^2}$$
$$R_L^{BD} = \frac{\bar{\theta}^2 q_H q_L\left[4q_H - q_L(1+3a)\right]^2}{16\left(q_H - q_L\right)\left(4q_H - q_L\right)^2} \tag{31}$$

Otherwise, the deviator becomes a monopolist. For the moment, we write the critical threshold of the discount factors by using (31):

$$\delta_H^B = \frac{(1-a)q_L\left(4q_H - q_L\right)^2}{\left(2q_H - q_L\right)\left[16q_H^2 - 2q_H q_L(7+a) + q_L^2(1-a)\right]}; \tag{32}$$

$$\delta_L^B = \frac{(1-a)\left(4q_H - q_L\right)^2}{3q_L\left[8q_H - q_L(5+3a)\right]}: \tag{33}$$

Again, the above thresholds are independent of $\bar{\theta}$; and can be plotted over the space $\{a; q_L\}$; after setting $q_H = 1$. This is done in figures 3 and 4, where the range of both plots is bounded above at 1/2, corresponding to the critical level of discounting associated with a joint venture.[13]

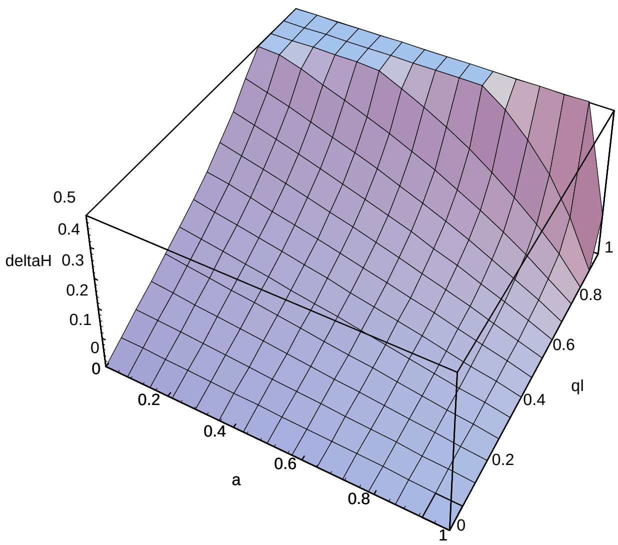

Figure 3. Plot of $\pm_H^B$ over $fa; q_L g$, with a 2 $[0; 1]$ and q_L 2 $[0; 1]$.

[13] As in the Cournot case, whenever $\pm_i^B < 0$ because deviation is unpro…table, the relevant threshold becomes $\pm_i^B = 0$:

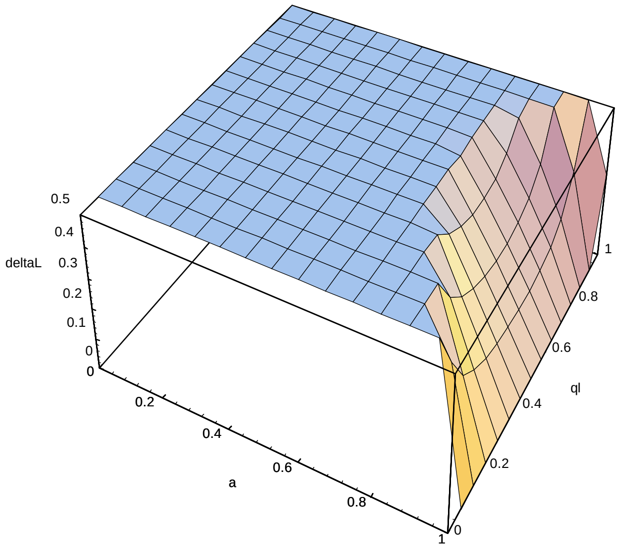

Figure 4. Plot of δ_L^B over $\{a; q_L\}$, with $a \in [0;1]$ and $q_L \in [0;1]$.

Consider first δ_L^B (figure 4). We have:

$$\delta_L^B = \frac{1}{2} \tag{34}$$

if

$$\frac{q_L}{q_H} = \frac{4\left[5 - 2a \pm 3\sqrt{2a^2 - 1}\right]}{17 + 7a}. \tag{35}$$

The above solutions coincide at $a = 1/\sqrt{2} \simeq 0.707$, where $q_L \simeq 0.653$.

Then, observe the behaviour of δ_H^B (figure 3). The border along which $\delta_H^B = 1/2$ is everywhere to the north-west of the border (35).

Moreover, the curve $x_H^{BD} = \bar{\mu}$ is also to the north-west of the border (35).[14]

[14] Indeed, the equation

$$\frac{4\left[5 - 2a + 3\sqrt{2a^2 - 1}\right]}{17 + 7a} = \frac{7 - a - \sqrt{a^2 - 22a + 25}}{3 + a}$$

has no real root for $a \in [0;1]$; with the r.h.s. being always larger than the l.h.s. over the unit interval.

The cases where deviation gives rise to a monopoly remain to be investigated. This would entail recalculating δ_i^B anew, taking into account the additional information conveyed by the complements to (28) and (29). Yet, to the aims of the present paper, the following argument will suffice.

First, observe that, in general:

$$\frac{\partial \delta_i^I}{\partial R_i^{ID}} = \frac{R_i^{Icoll} - R_i^{IN}}{\left(R_i^{ID} - R_i^{IN}\right)^2} > 0. \tag{36}$$

At the boundary where $x_H^{BD} = \bar{\theta}$; critical discount factors are given by (32) and (33). When

$$\frac{q_L}{q_H} \in \left(\frac{7 - a - \sqrt{a^2 - 22a + 25}}{3 + a}, \frac{19 - 3a - \sqrt{9a^2 - 114a + 169}}{8} \right); \tag{37}$$

the critical discount factor for firm L is still given by (33), while that associated to firm H is:

$$\hat{\delta}_H^B = \frac{R^M - R_H^{Bcoll}}{R^M - R_H^{BN}} > \delta_H^B = \frac{R_H^{BD} - R_H^{Bcoll}}{R_H^{BD} - R_H^{BN}} > \frac{1}{2}. \tag{38}$$

Finally, when

$$\frac{q_L}{q_H} > \frac{19 - 3a - \sqrt{9a^2 - 114a + 169}}{8}; \tag{39}$$

we have

$$\hat{\delta}_L^B = \frac{R^M - R_L^{Bcoll}}{R^M - R_L^{BN}} > \delta_L^B = \frac{R_L^{BD} - R_L^{Bcoll}}{R_L^{BD} - R_L^{BN}} > \frac{1}{2}; \tag{40}$$

along with (38).

The above discussion suffices to establish the following result:

Proposition 2 Implicit collusion in prices is more easily sustained under independent ventures than under a joint venture, for all

$$\frac{q_L}{q_H} \in \left(\frac{4\left[5 - 2a - 3\sqrt{2a^2 - 1}\right]}{17 + 7a}; \frac{4\left[5 - 2a + 3\sqrt{2a^2 - 1}\right]}{17 + 7a} \right)$$

Outside the above range, the opposite holds.

As the intensity of collusion decreases towards the Bertrand-Nash equilibrium profits, i.e., as a grows larger, the range of product differentiation wherein collusion is easier under IV than under JV increases. The intuitive explanation behind this conclusion is the same as in the Cournot case.

5 Concluding remarks

We have reassessed an issue previously raised by Martin (1995), under a new perspective, where firms' initial R&D efforts are aimed at product rather than process innovation. We have analysed the relationship between the organizational design of R&D for product innovation and the stability of implicit collusion either in quantities or in prices, keeping unaltered the rules governing the market supergame, i.e., using the Perfect Folk Theorem.

The main conclusion emerging from this setting is that a JV may or may not facilitate collusion in the market supergame, depending upon (i) the degree of differentiation produced by firms activating independent ventures; and (ii) the intensity of price or quantity collusion.

Independently of the market variable being set by firms, we have found that, the lower is the level of collusion, the lower is the profitability of deviation for any given degree of product differentiation resulting from independent ventures. This drastically contributes to stabilise implicit collusion, in that a reduction of deviation profits goes along with a reduction in the critical threshold of the discount factor.

Therefore, public policies towards R&D behaviour should be designed so as not to become inconsistent with the pro-competitive attitude characterising the current legislation on marketing practices.

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